Experimental Measurements of the 1/8th-Scale Ground Transportation System in the NASA Ames 7- by 10-Ft Wind Tunnel

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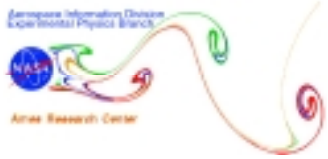
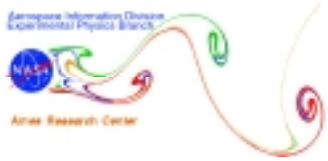


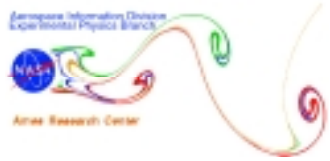
Outline

- Objectives
- Model Details
- Test Matrix
- Measurements
- Results
- Summary



Objectives

- Provide experimental data for CFD validation.
  - Both on-body and off-body measurements
  - Time-averaged and limited dynamic data
- Demonstrate a simple drag reduction technique that is easily modeled in computations.



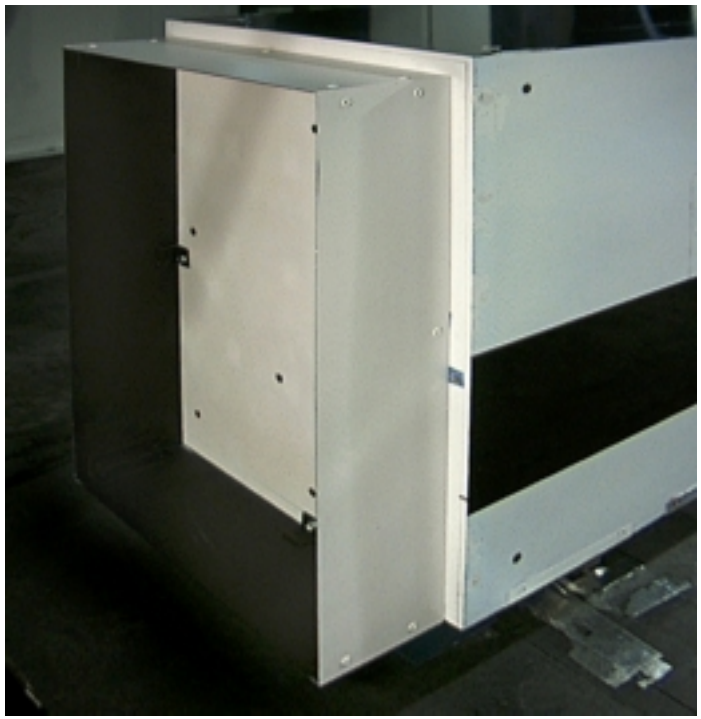
Ground Transportation System (GTS) Model

- Simplified Geometry
  - Cab over design
  - No gap
  - No wheels
- 1/8th Scale
  - Length: 97.5 in.
  - Height: 17.75 in.
  - Width: 12.75 in.

Installation of GTS model in NASA Ames 7x10 wind tunnel

Drag Reducing Boattail Plates

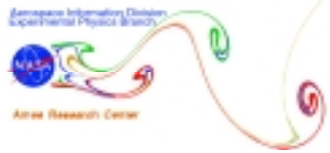
- Developed by Continuum Dynamics, Inc.
- Dimensions:
  - Length: 3.75 in.
  - Height: 17.125 in.
  - Width: 11.25 in.
- Full-Scale Length = 2.5 ft



Boattail plates installed on back of truck

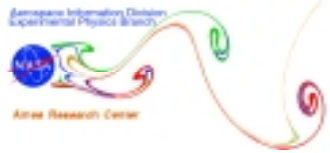
Test Matrix

- Model configuration: w & w/o boattail plates
- Yaw angle: ±14 deg
- Tunnel Conditions:
  - Mach = 0.27 and 0.10
  - Reynolds number = 2 million and 740,000
    - Full-Scale Re = 5 - 6 million
  - Re variation from 300,000 to 2 million (zero yaw)

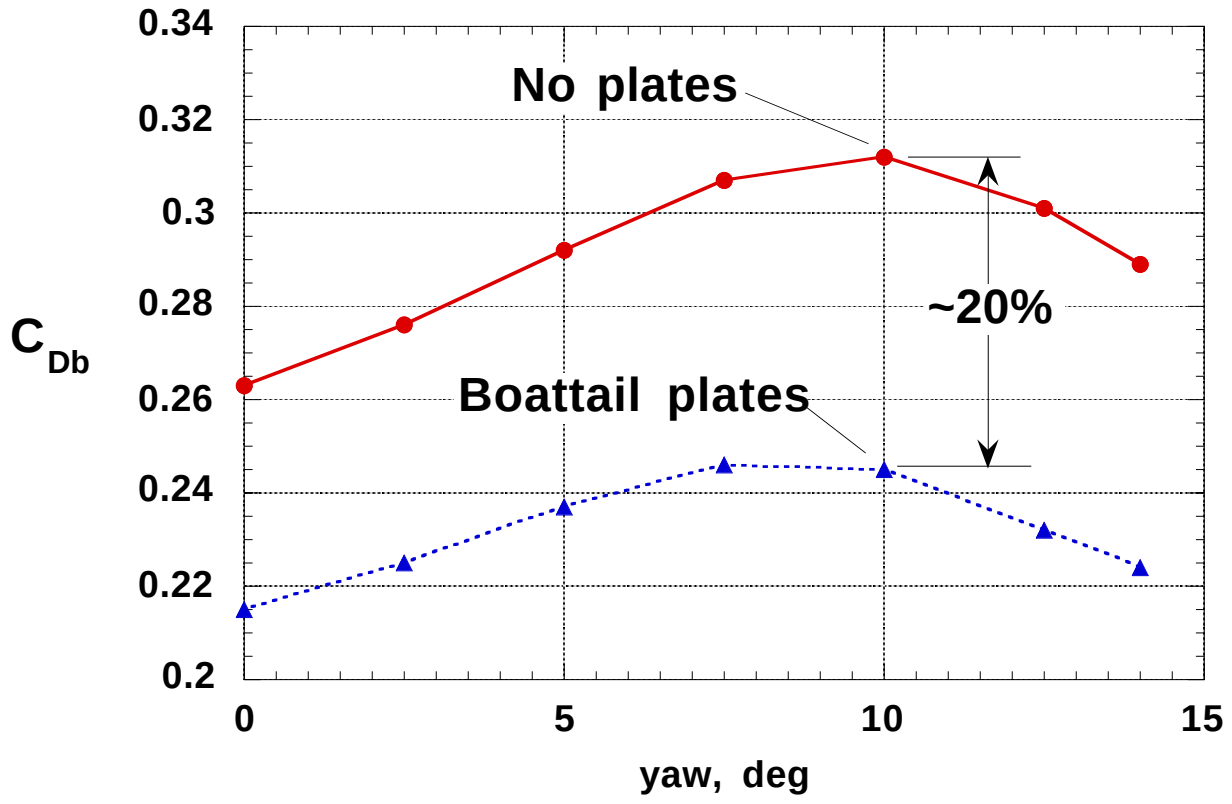


Measurements

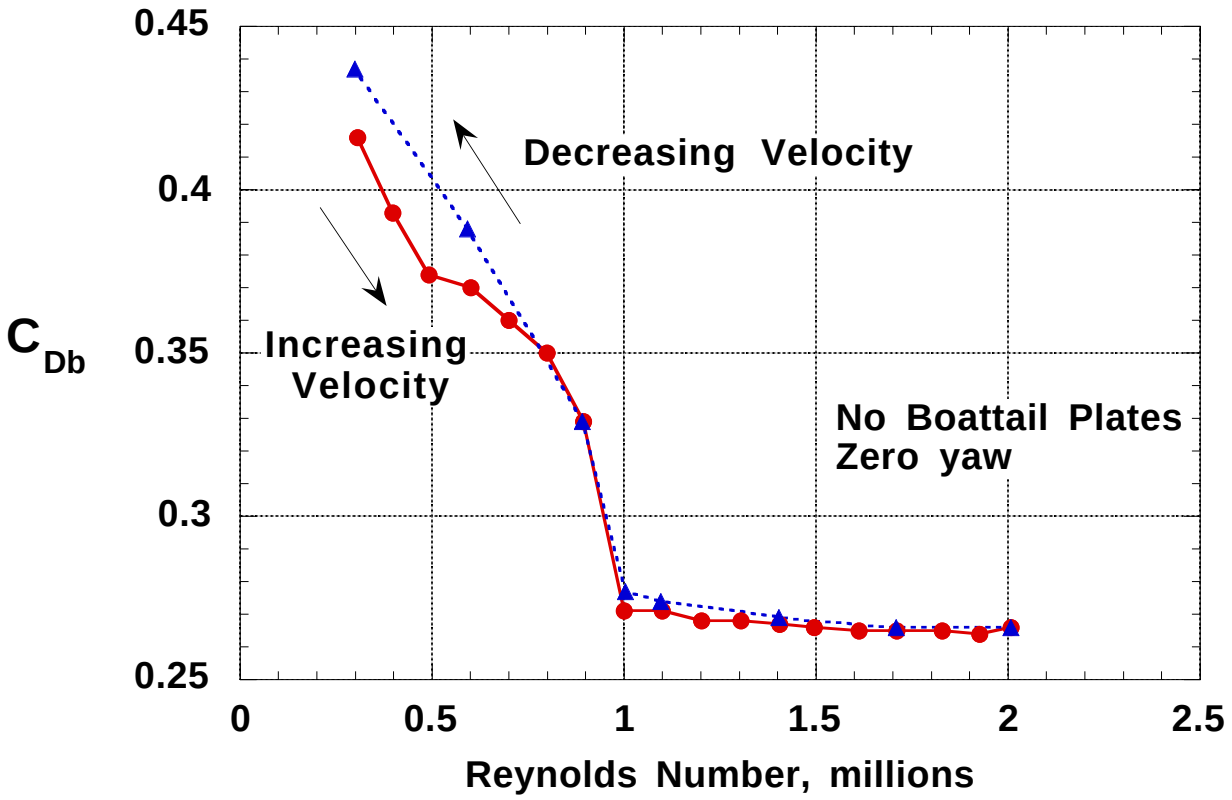
- Forces and moments
- Surface pressures
  - Static pressure taps
  - Pressure-Sensitive Paint
  - Unsteady pressure
- Skin friction from Oil-Film Interferometry
- Separation/Transition detection
- 3D Particle Image Velocimetry



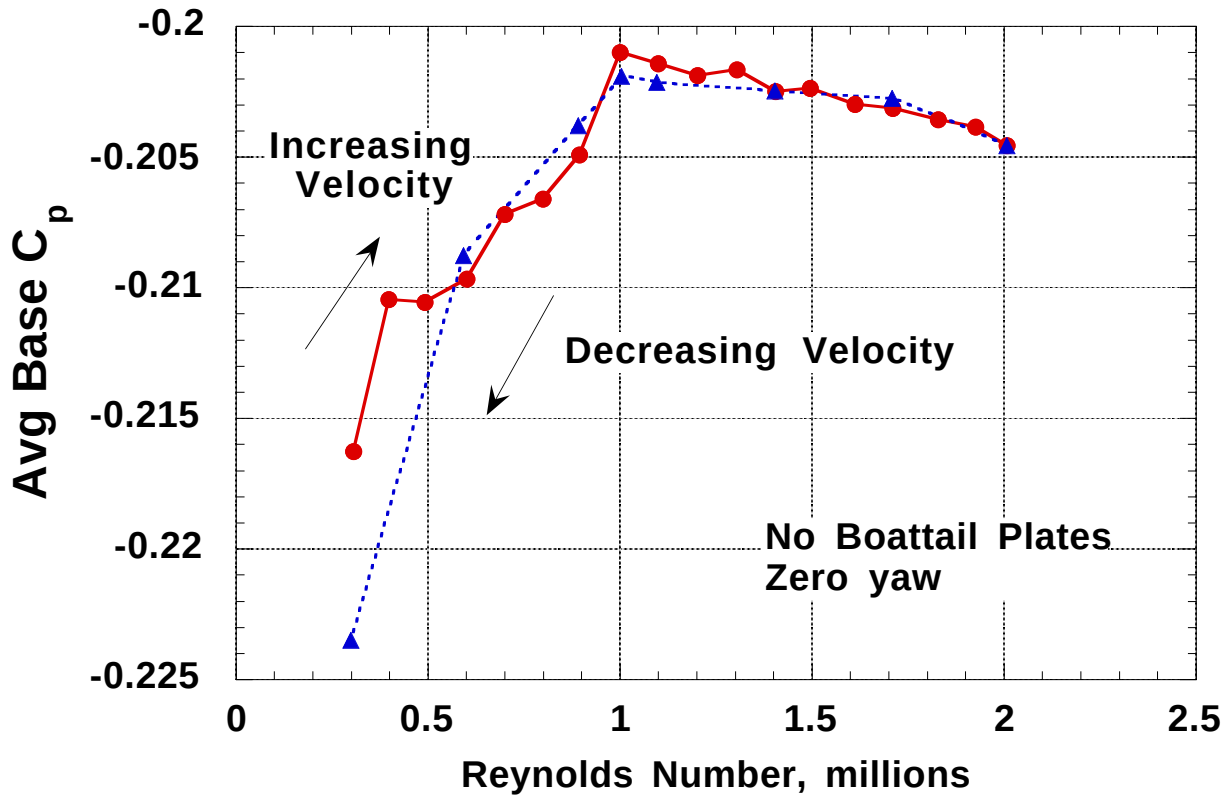
Effect of Boattail Plates on Drag



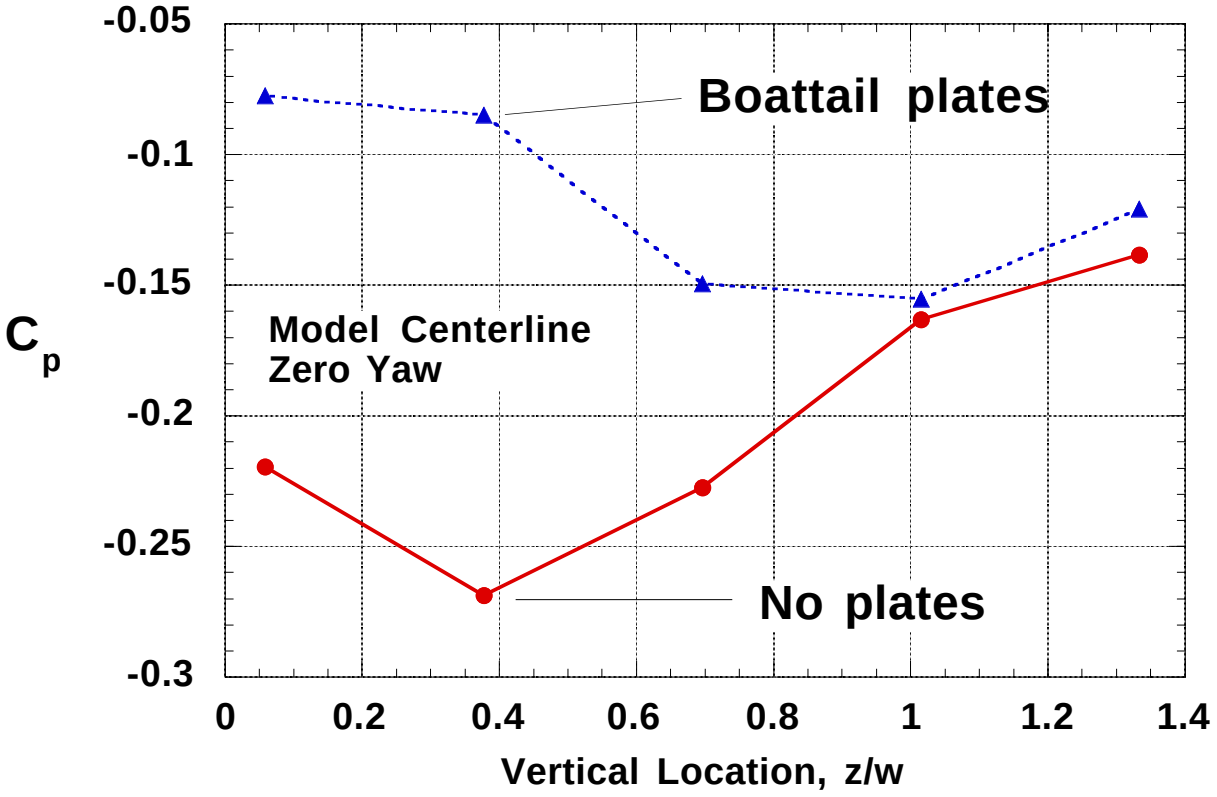
Effect of Reynolds Number on Drag

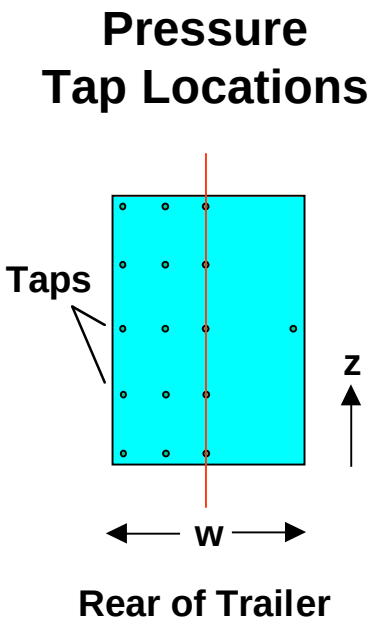


Effect of Reynolds Number on Base Pressure



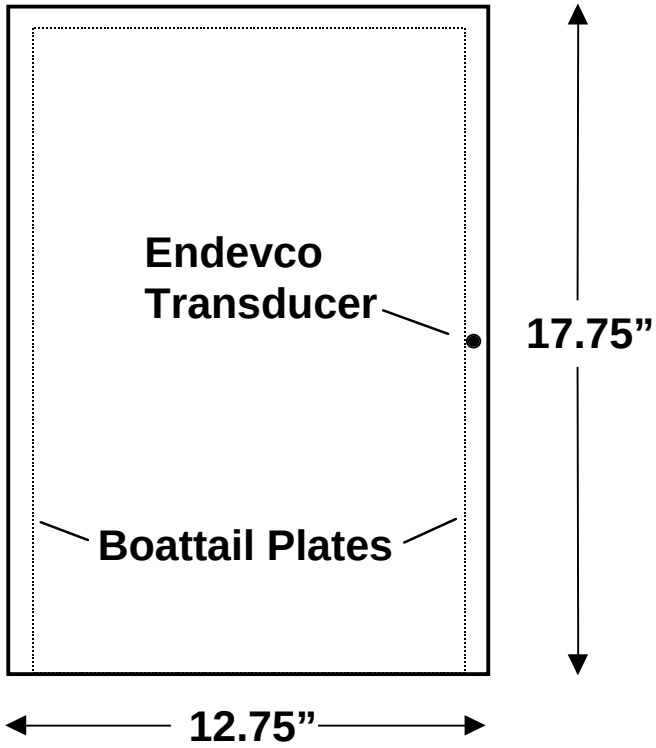
Effect of Boattail Plates on Base Pressure





Unsteady Pressure Measurement

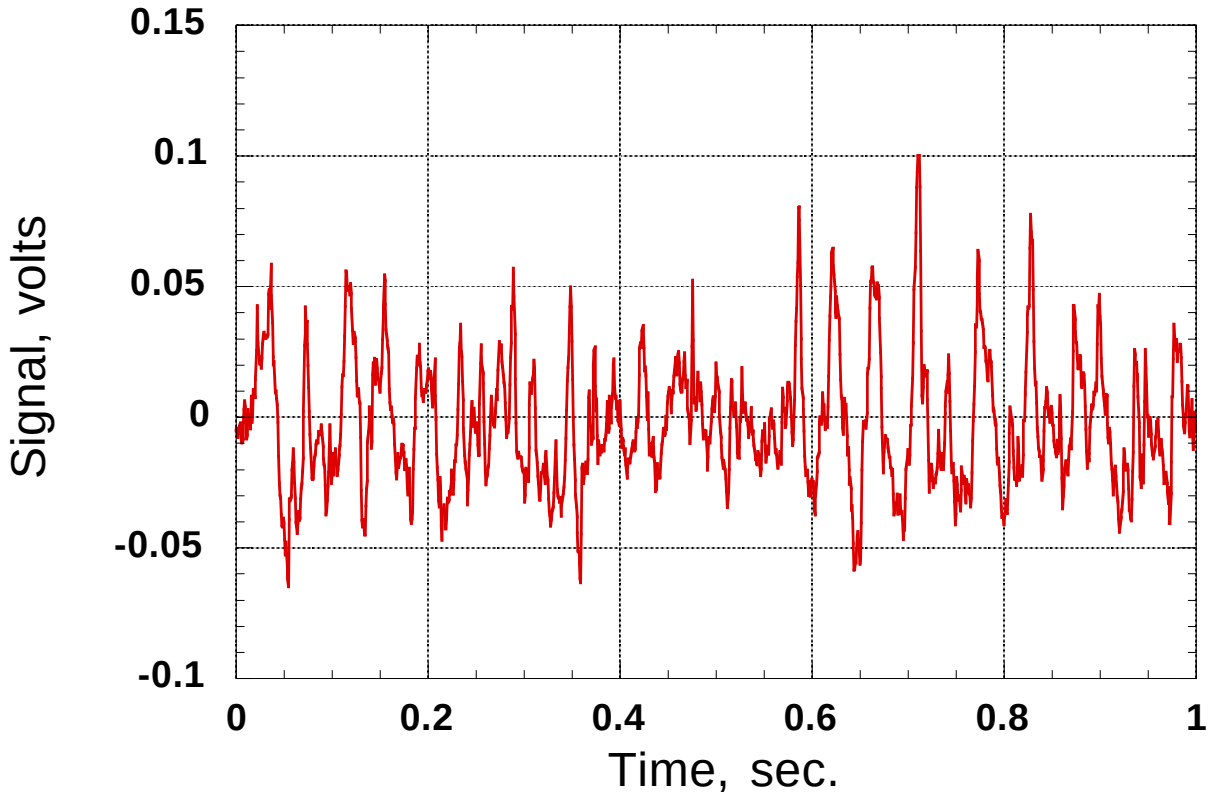
- 15 psia transducer, AC-coupled
- Mid-height on right side of rear door
- Center of transducer is 0.25 inch from side edge
- Measurements made w/ and w/out boattail plates



Sensor location on back of truck

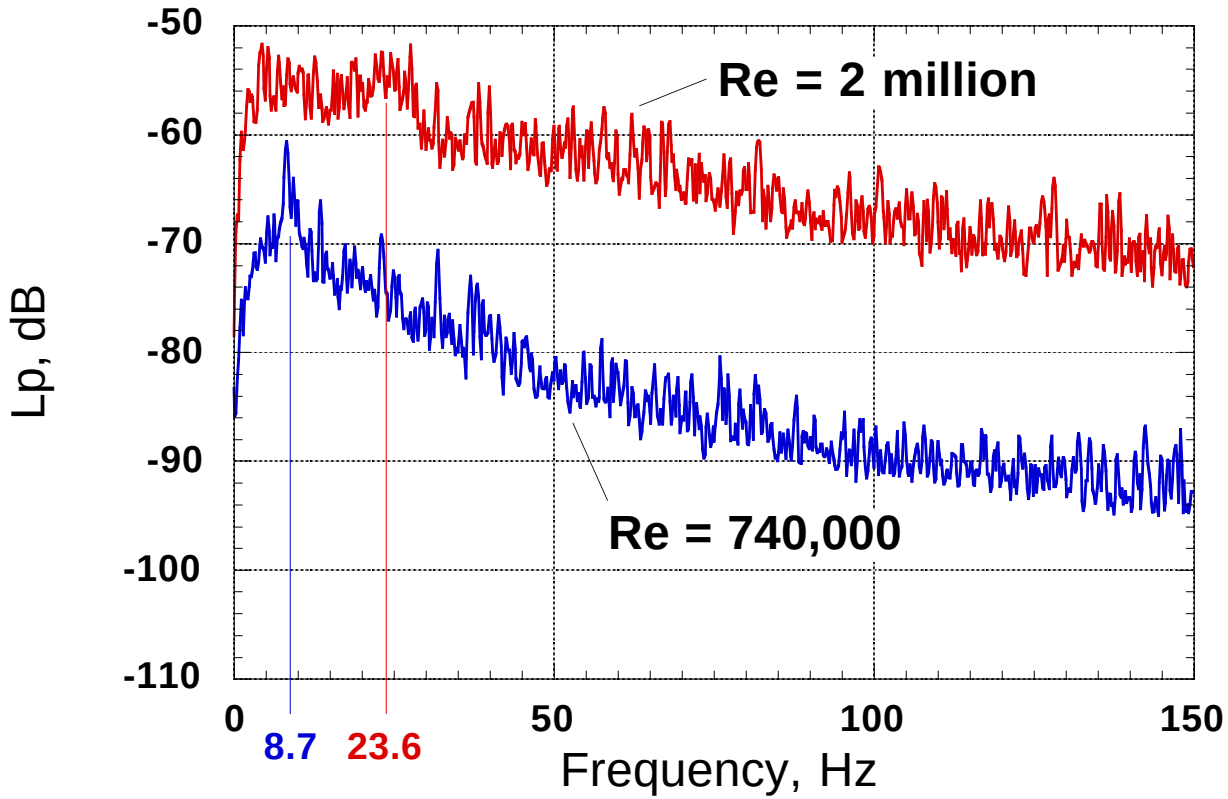
Unsteady Pressure Signal

No Boattail plates, Yaw = 0 deg, Re = 2 million



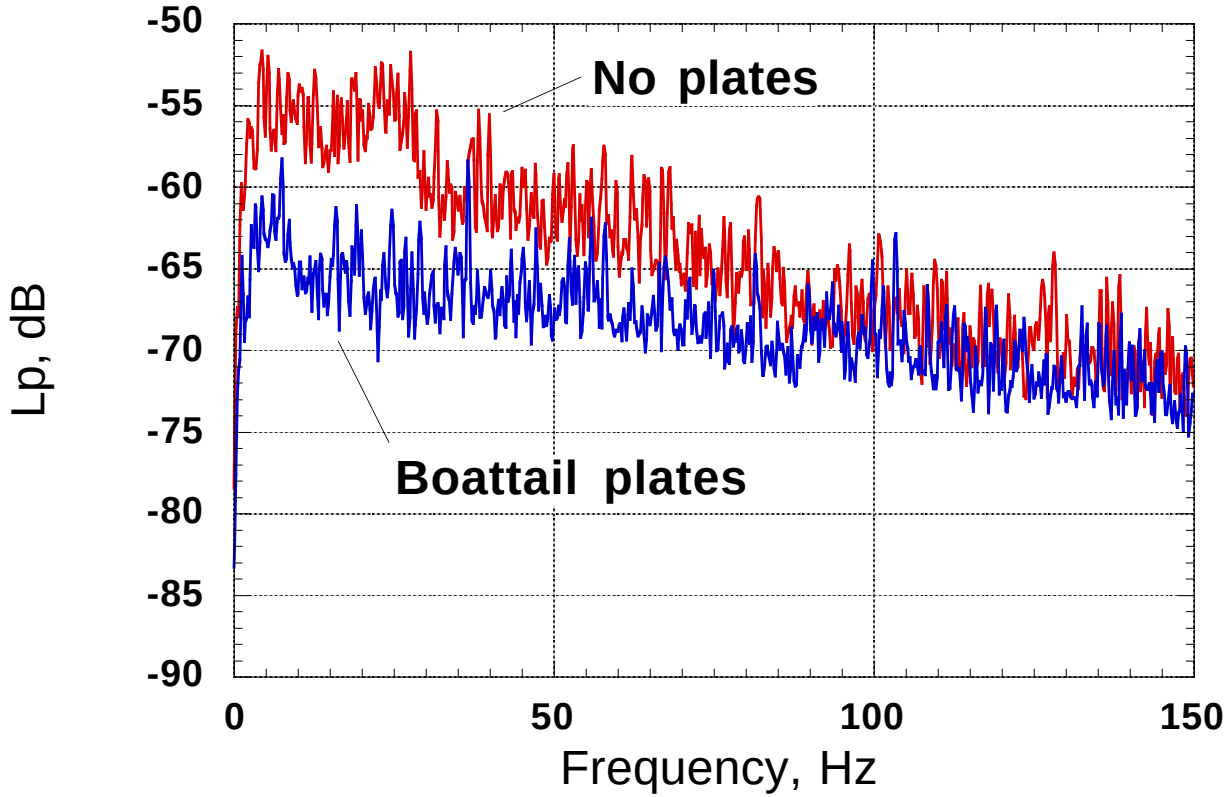
Effect of Reynolds Number on Unsteady Pressure Spectra

No Boattail plates, Yaw = 0 deg

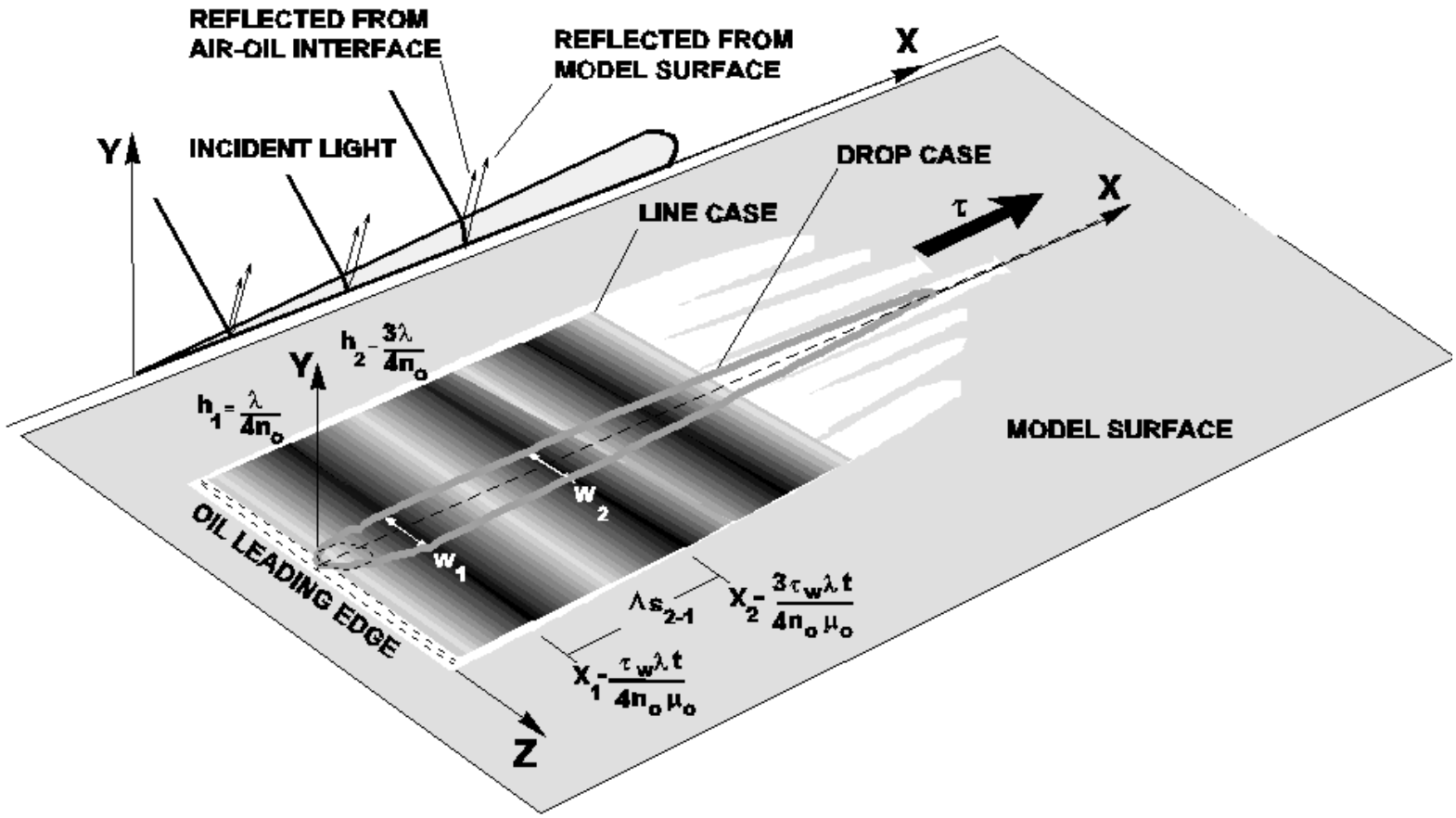


Effect of Boattail Plates on Unsteady Pressure Spectra

Yaw = 0 deg, Re = 2 million



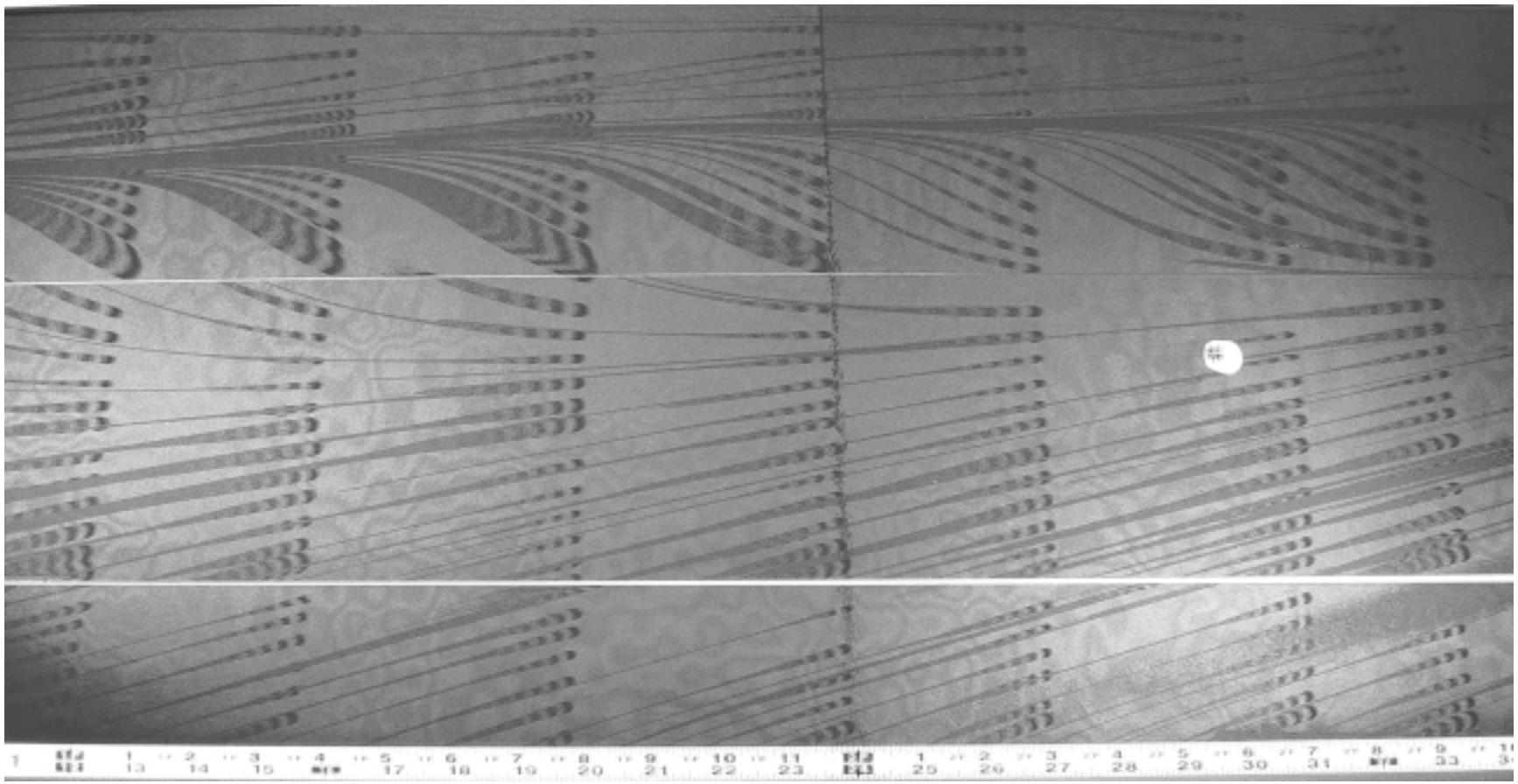
Oil-Film Interferometry



Oil-Film Interferometry

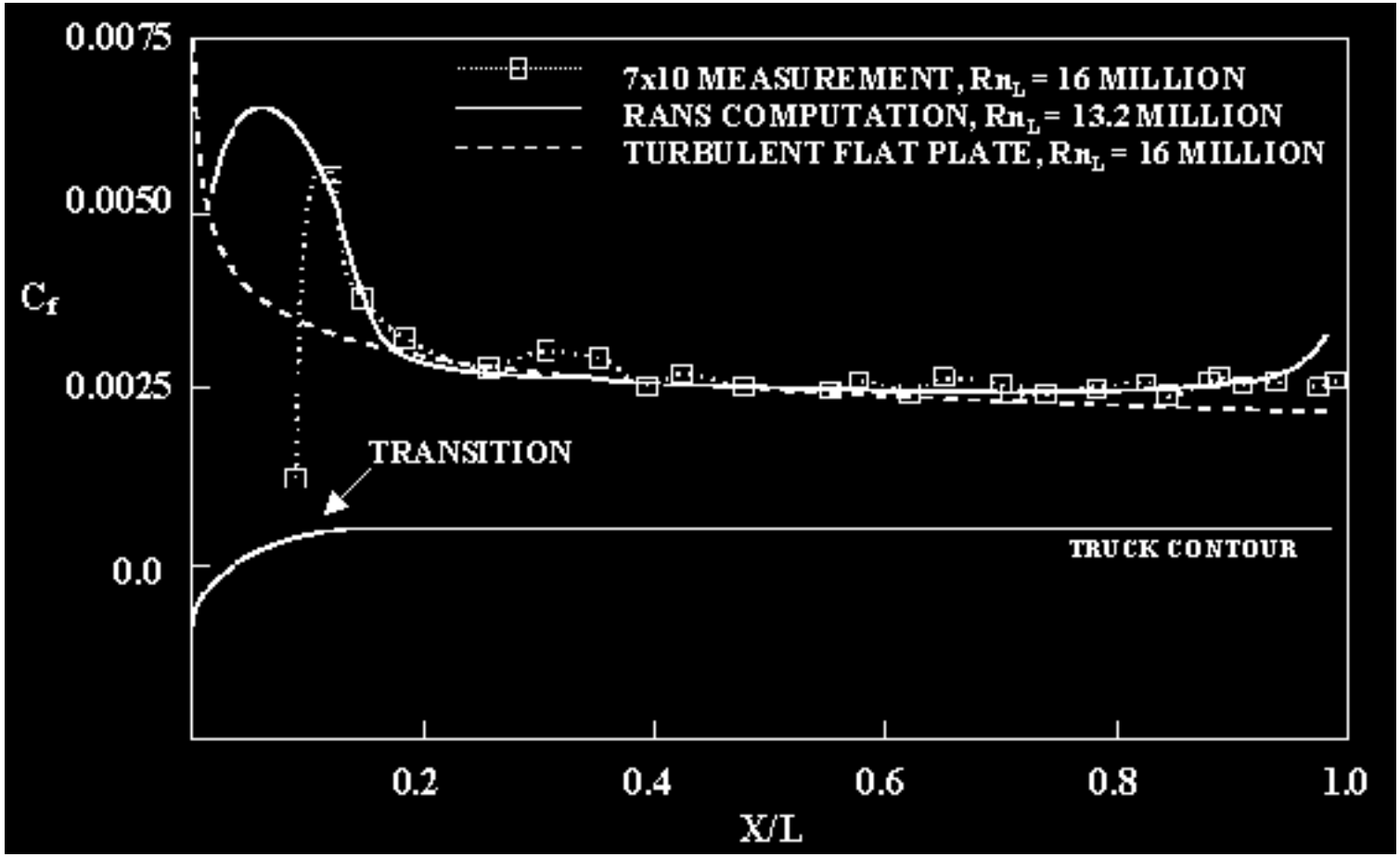
V

Top View of Trailer at 10-deg Yaw, No Boattail plates



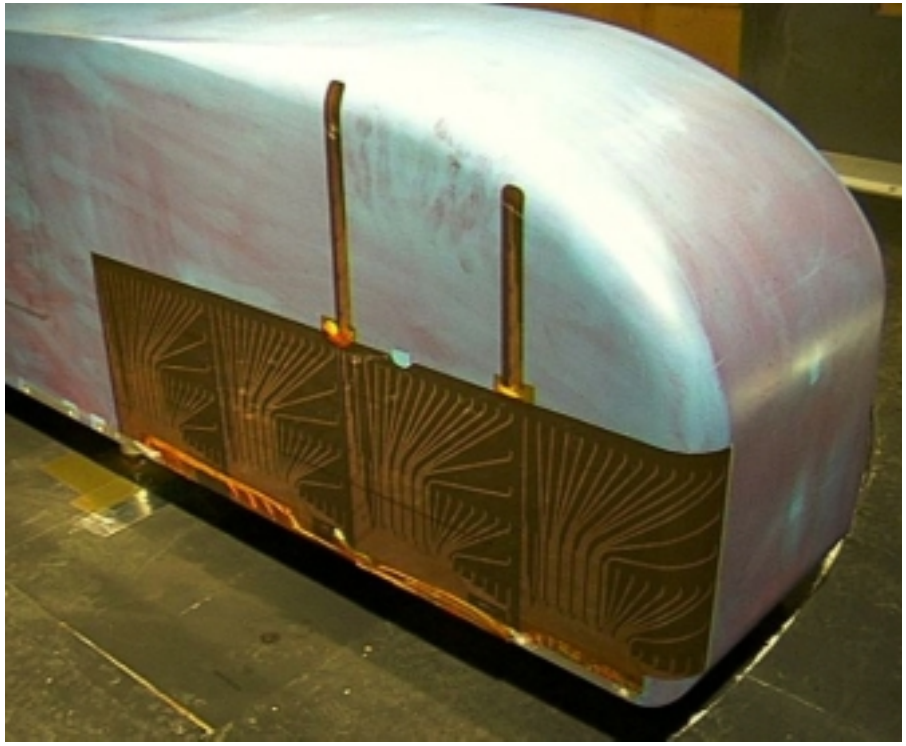
Skin friction proportional to fringe spacing

Oil-Film Interferometry



Transition/Separation Detection with Hot Film

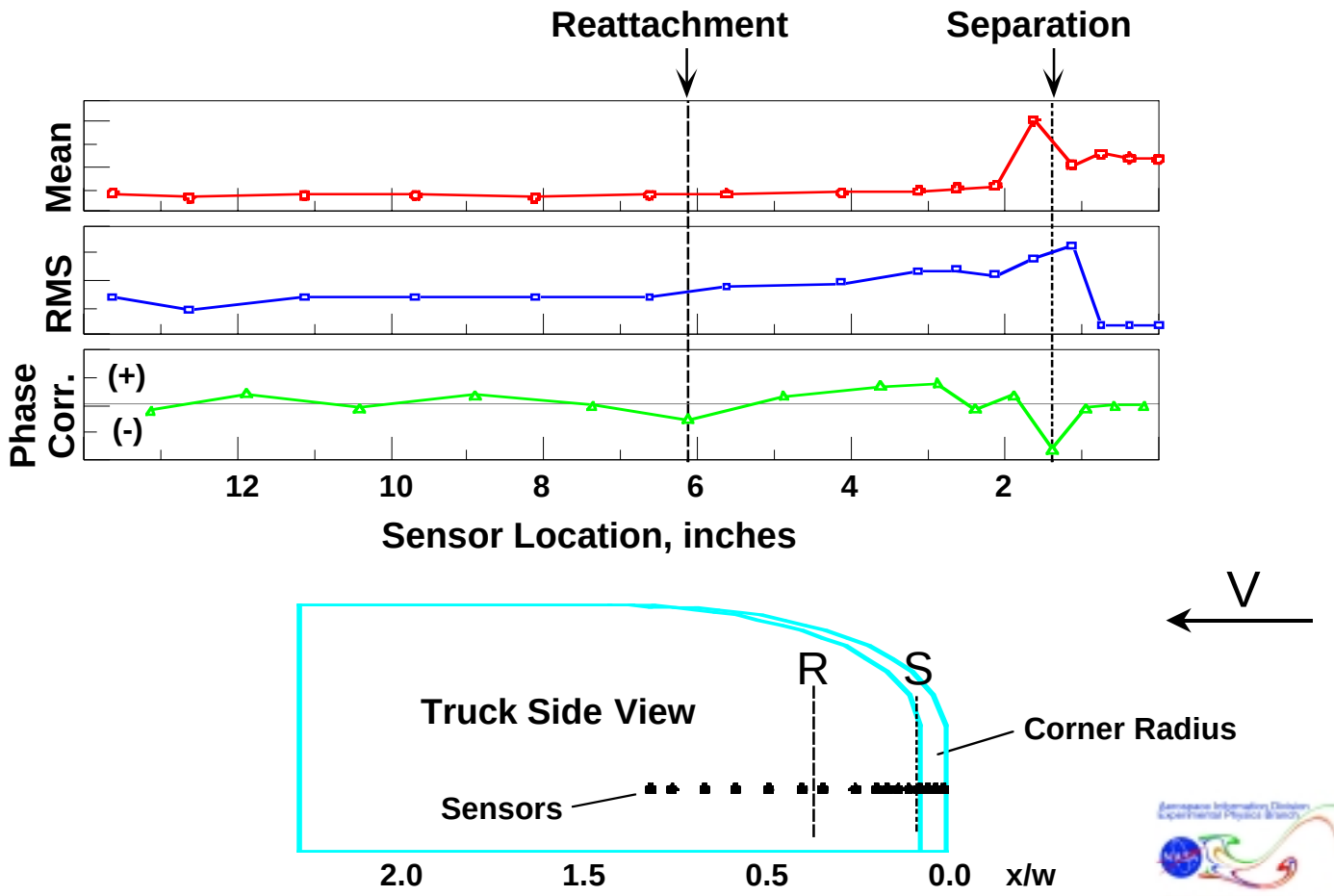
- Conducted by Tao Systems under SBIR
- 64 sensors on right side; 4 configurations
- RMS and intermittency factor reveal transition
- Phase correlations determine separation and reattachment



Hot-film sensors installed on GTS model

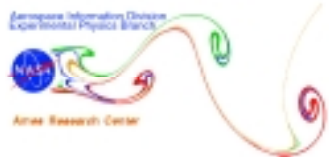
Hot Film Results

No Boattail plates, Yaw = 10 deg, Re = 2 million



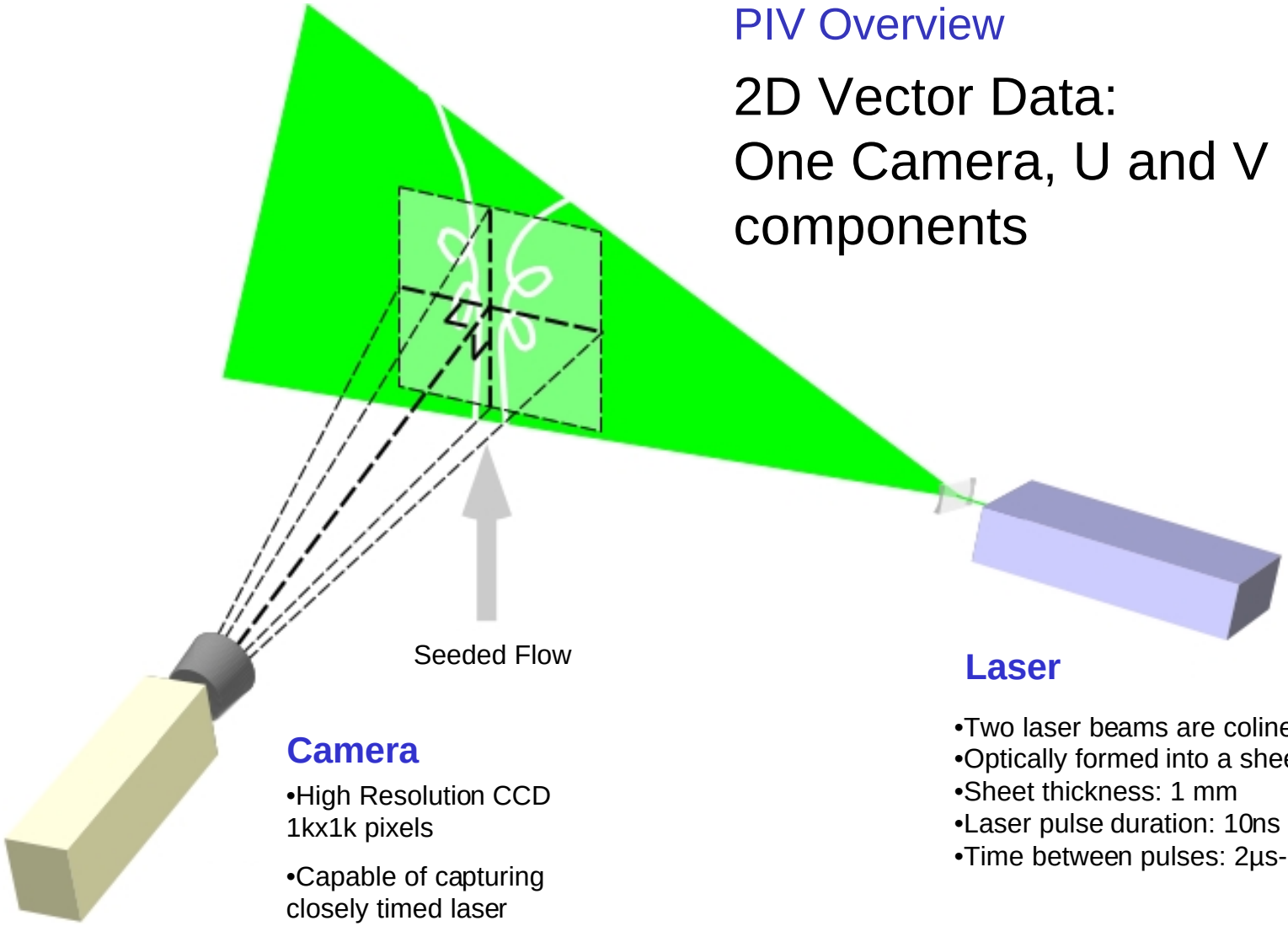
Particle Image Velocimetry: An Overview

- Produces vector data for a plane in a flow field
- Tracks flow-tracing particles in time using pulsed lasers
- Digital cameras record the particle displacement
- Image processing software calculates the direction and magnitude of displacements



PIV Overview

2D Vector Data: One Camera, U and V components



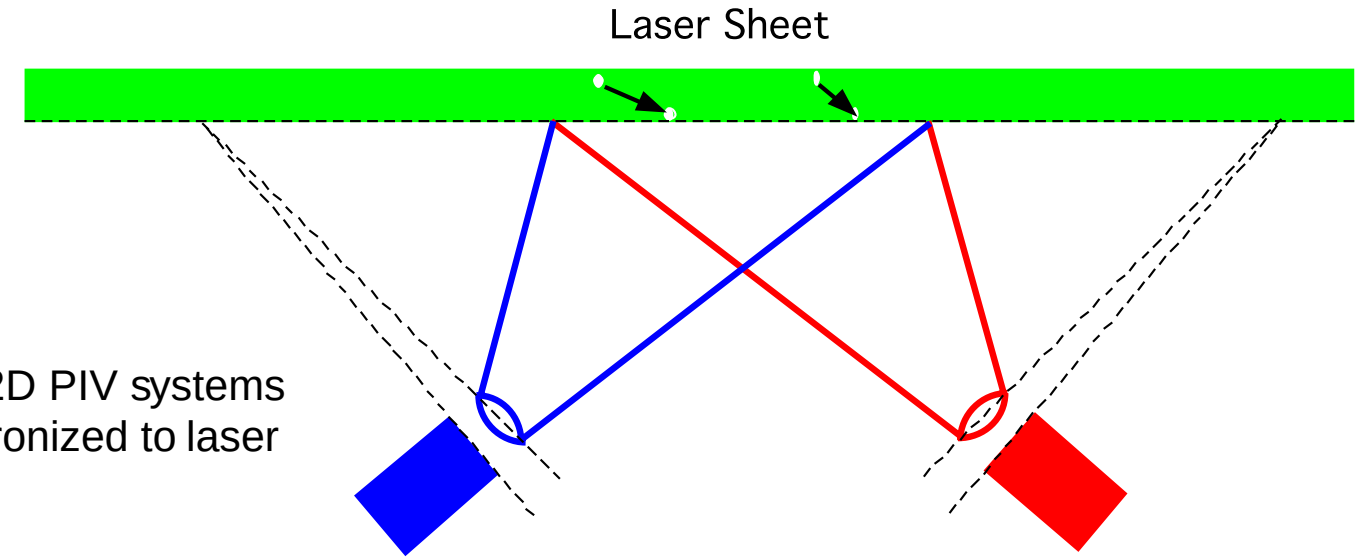
Camera

- High Resolution CCD 1kx1k pixels
- Capable of capturing closely timed laser pulses

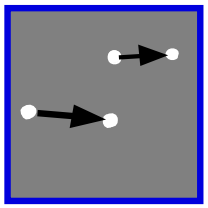
Laser

- Two laser beams are colinear
- Optically formed into a sheet
- Sheet thickness: 1 mm
- Laser pulse duration: 10ns
- Time between pulses: 2µs-16ms

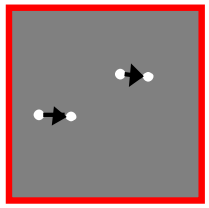
3D PIV: Stereoscopic Perspective Difference



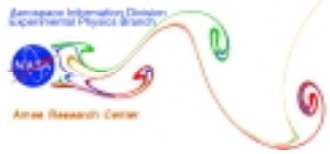
Two, 2D PIV systems synchronized to laser



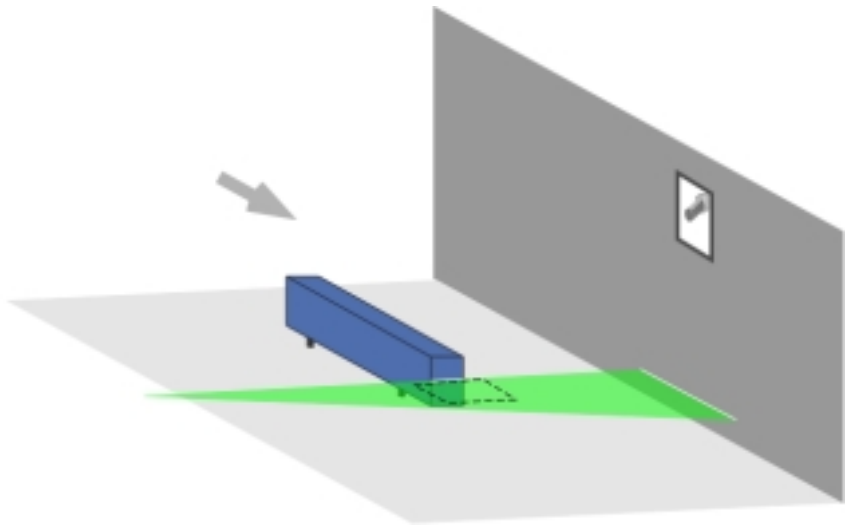
3D PIV Camera 1 View



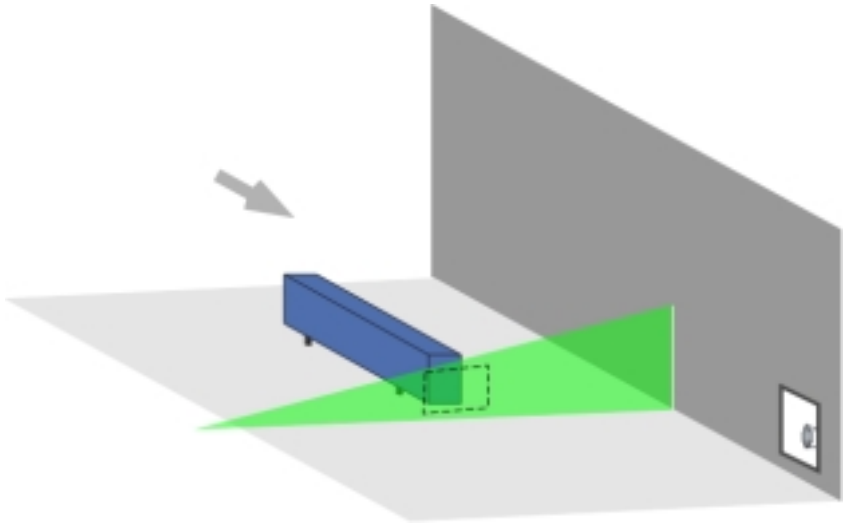
3D PIV Camera 2 View



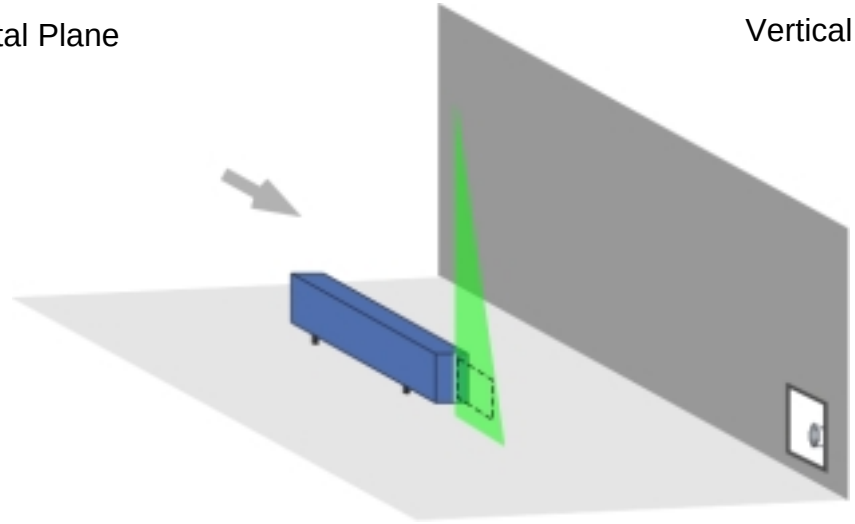
Laser Sheet and Camera Orientations



Horizontal Plane

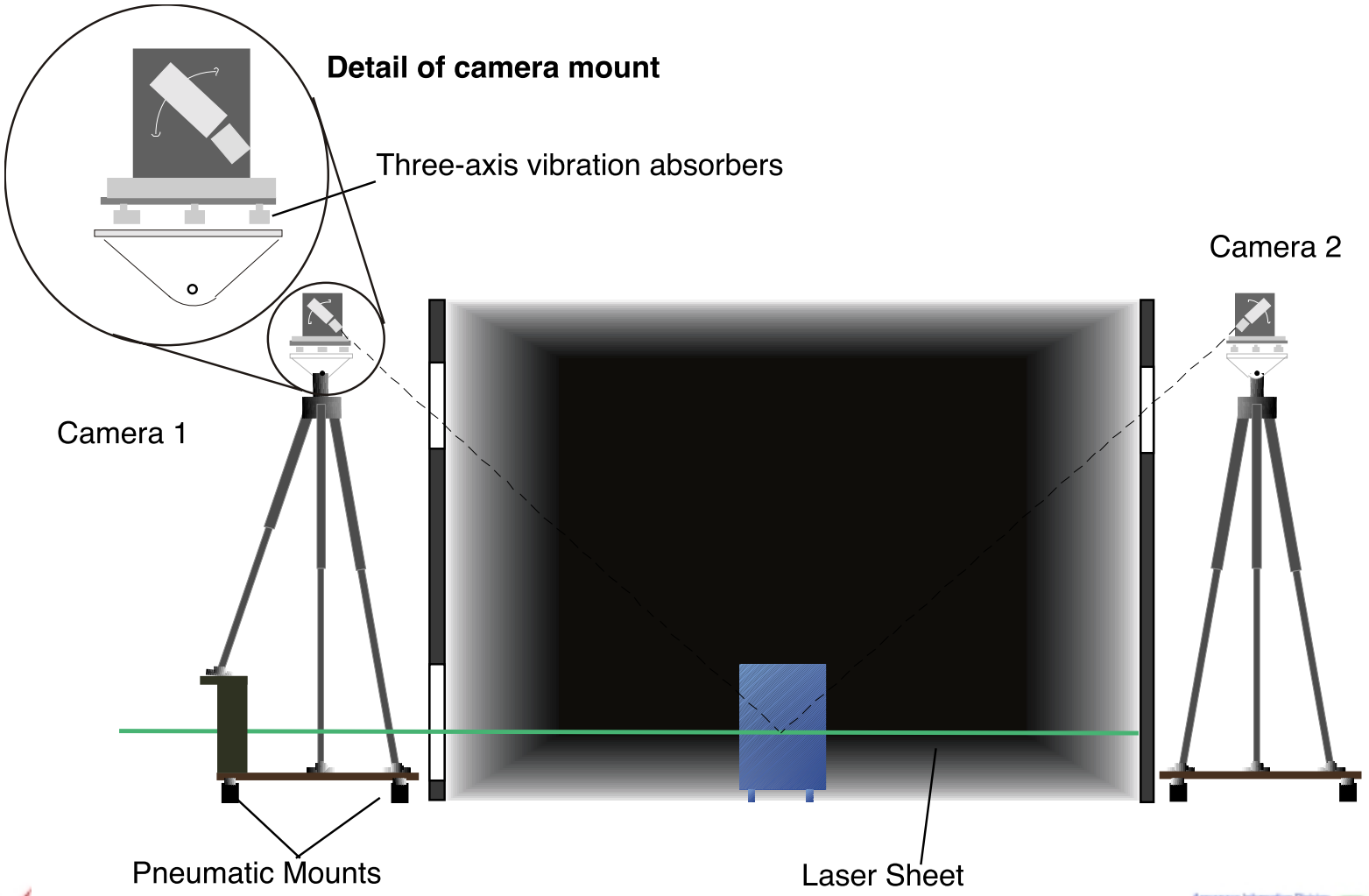


Vertical Cross-stream Plane

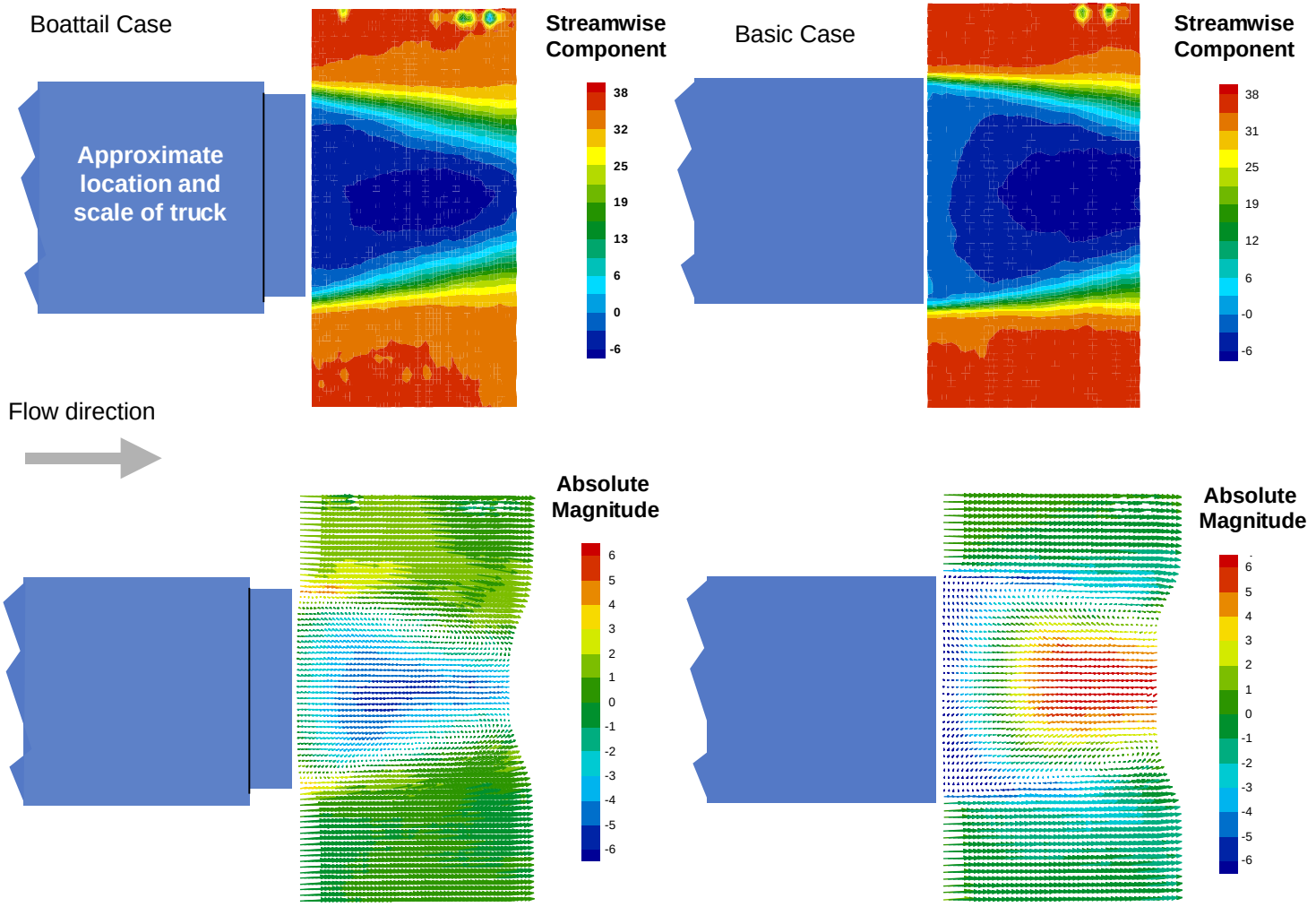


Vertical Streamwise Plane

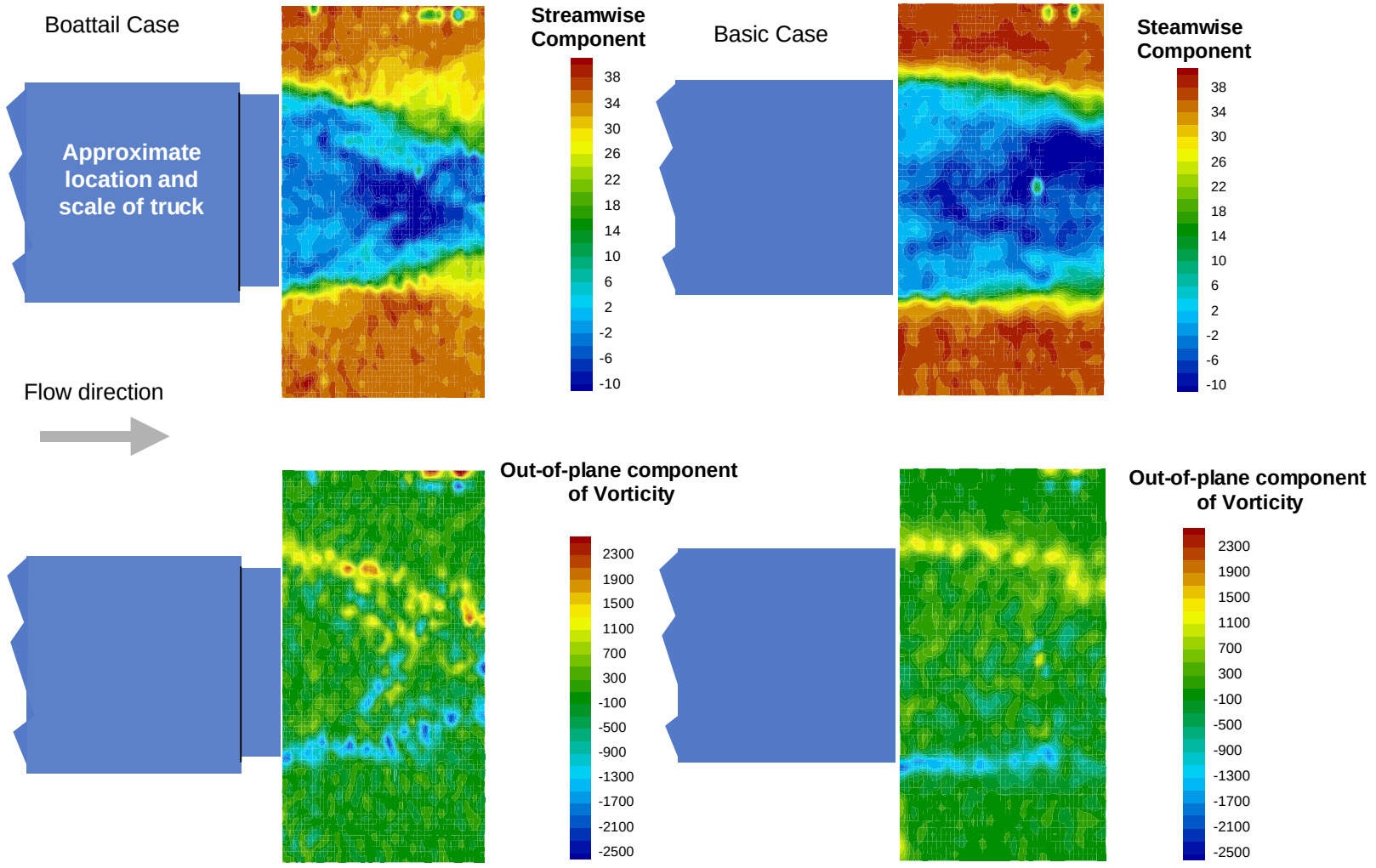
3D PIV in the NASA 7x10



View upstream of test section with horizontal laser plane and camera orientation

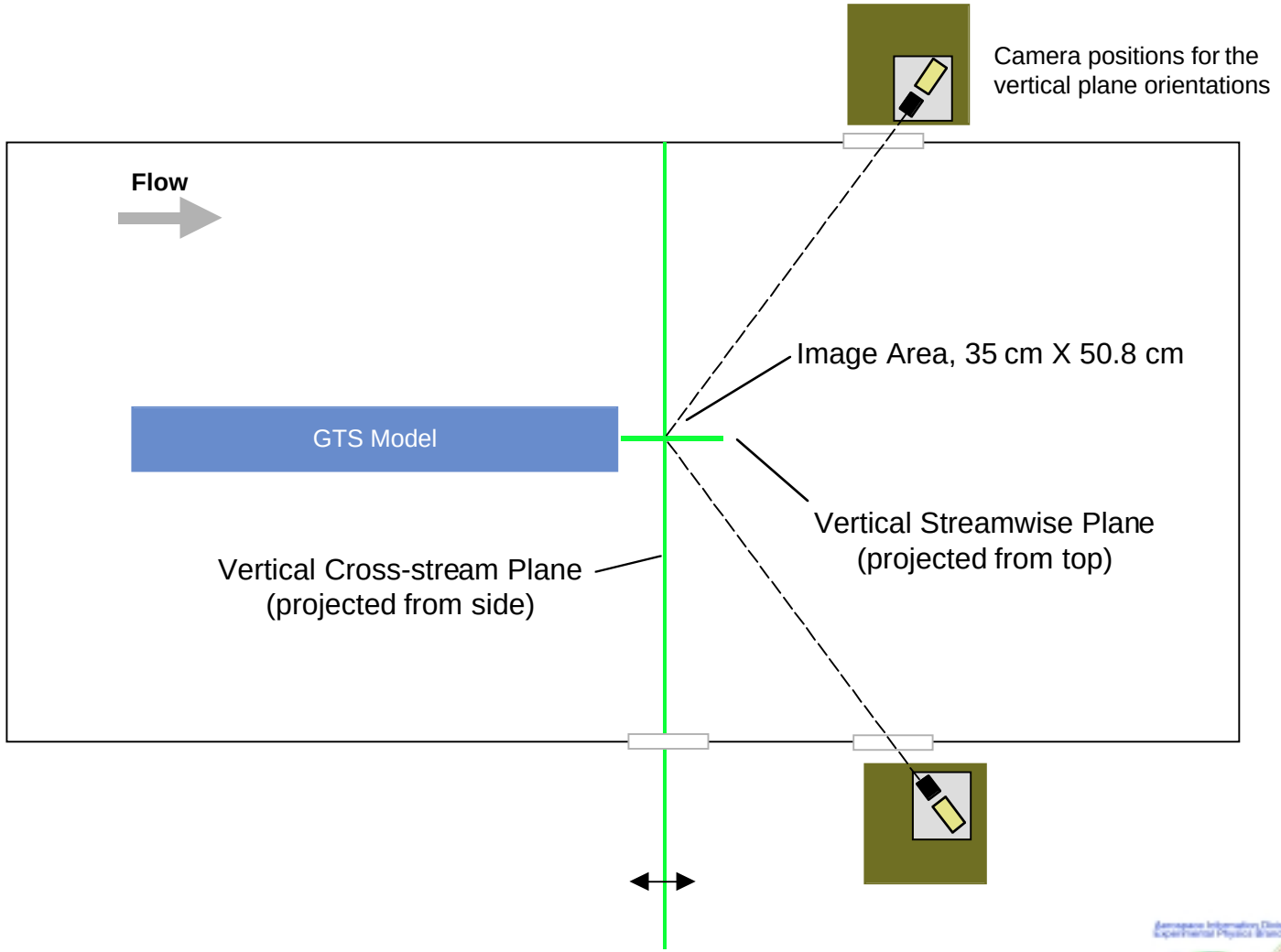


Horizontal plane at half-height, time averaged

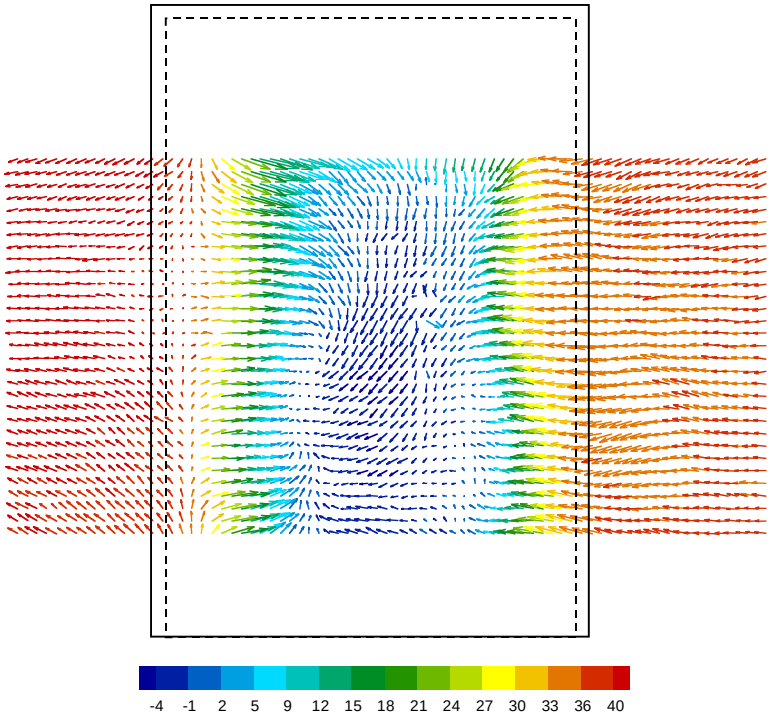


Horizontal plane at half-height, one measurement

Test Section - top view

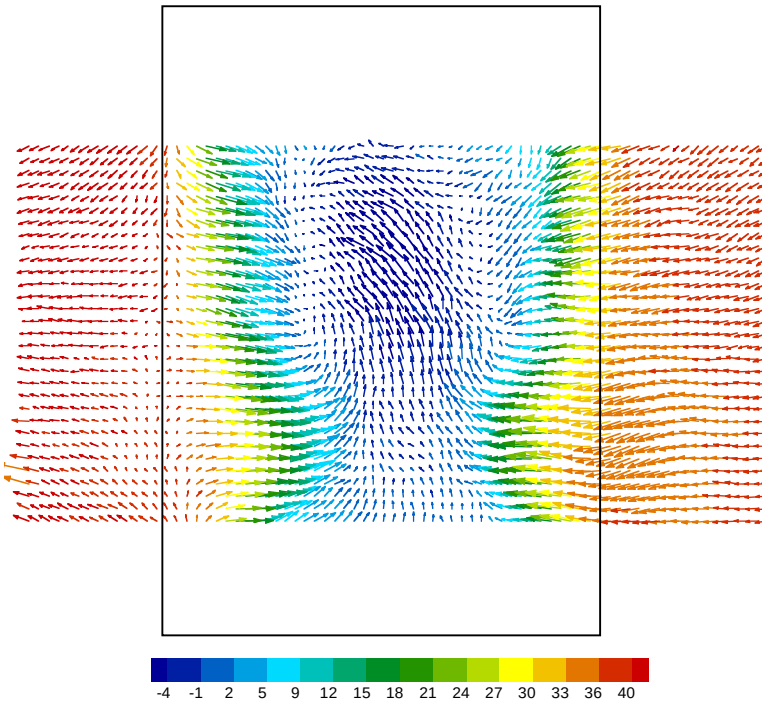


Boattail Case



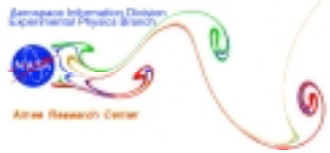
Streamwise Velocity, m/s

Basic Case



Streamwise Velocity, m/s

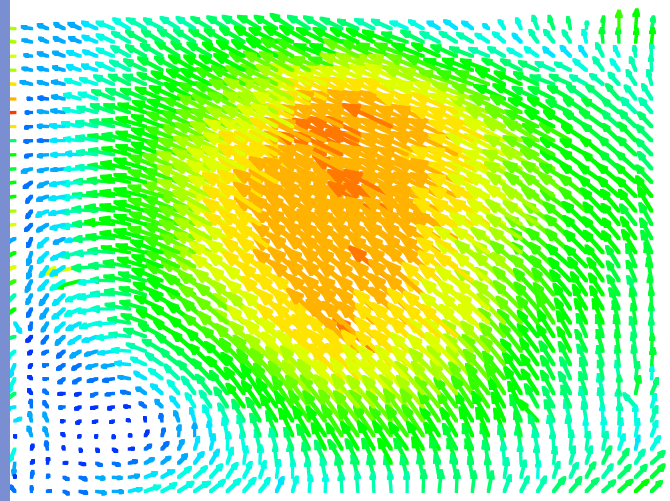
Cross-stream plane at 0.2 truck-lengths, time averaged

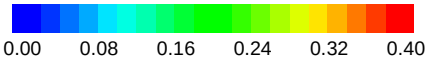


Flow

Approximate location and scale of truck

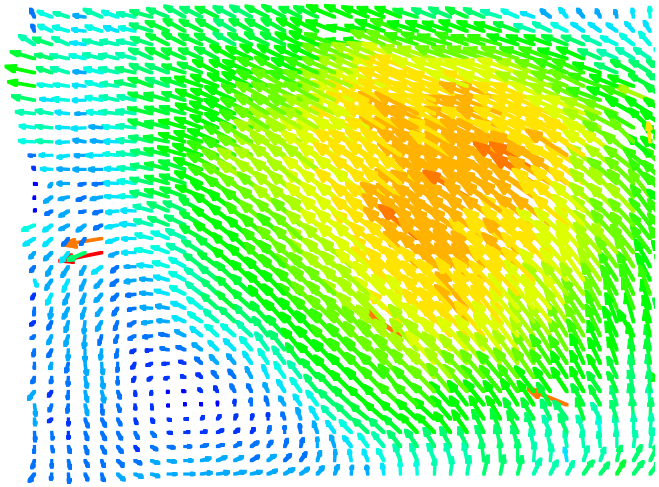
M= 0.10

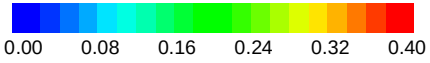




Absolute Magnitude of the Normalized Velocity

M= 0.27

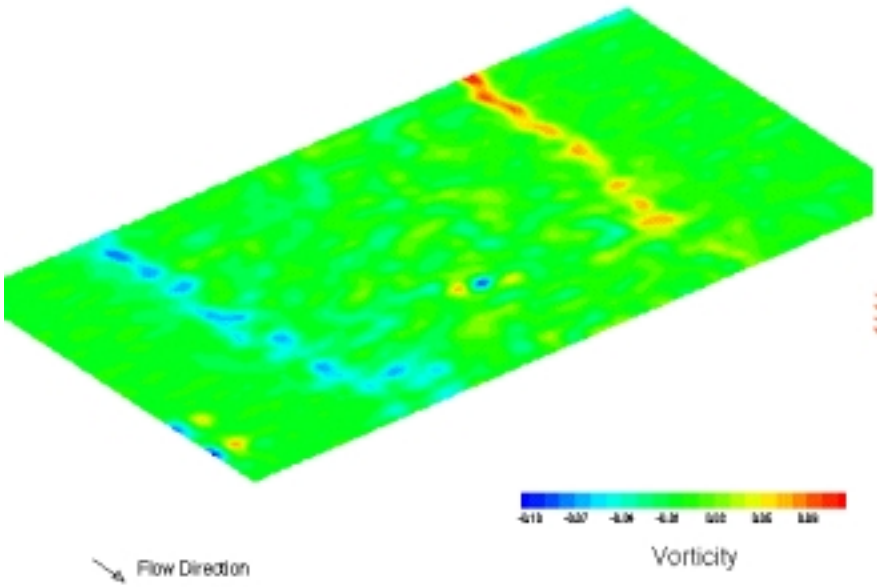




Absolute Magnitude of the Normalized Velocity

Steamwise plane at midwidth, time averaged

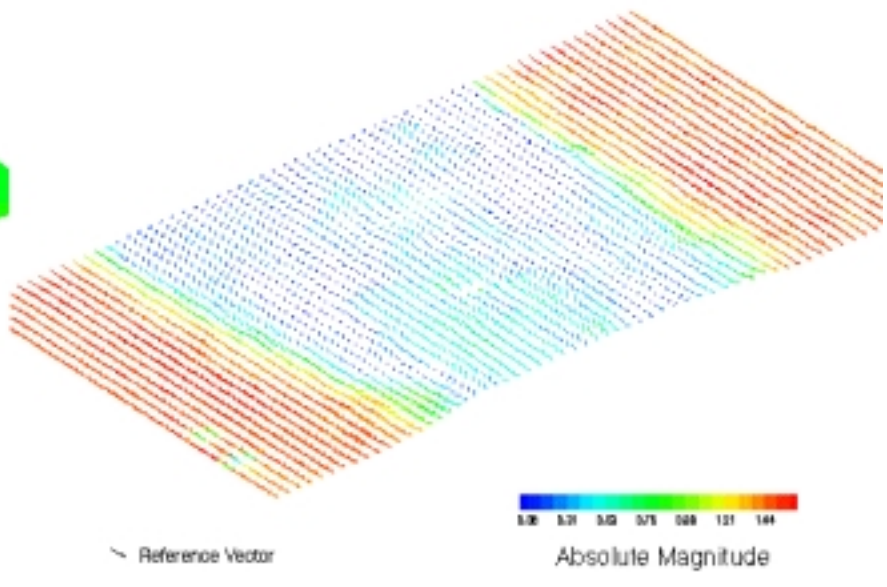
Basic Truck Case
Horizontal Plane at Half Height



Vorticity

Flow Direction

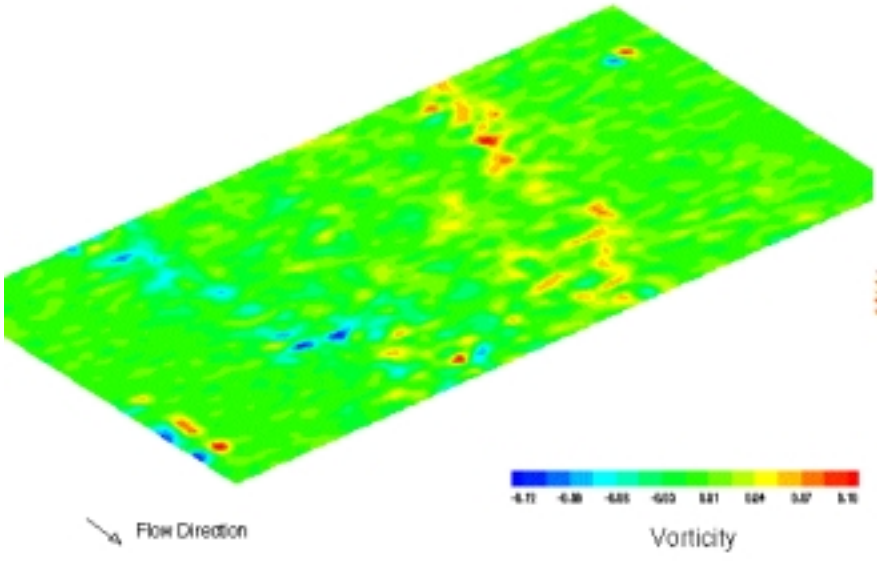
Basic Truck Case
Horizontal Plane at Half Height



Absolute Magnitude

Reference Vector

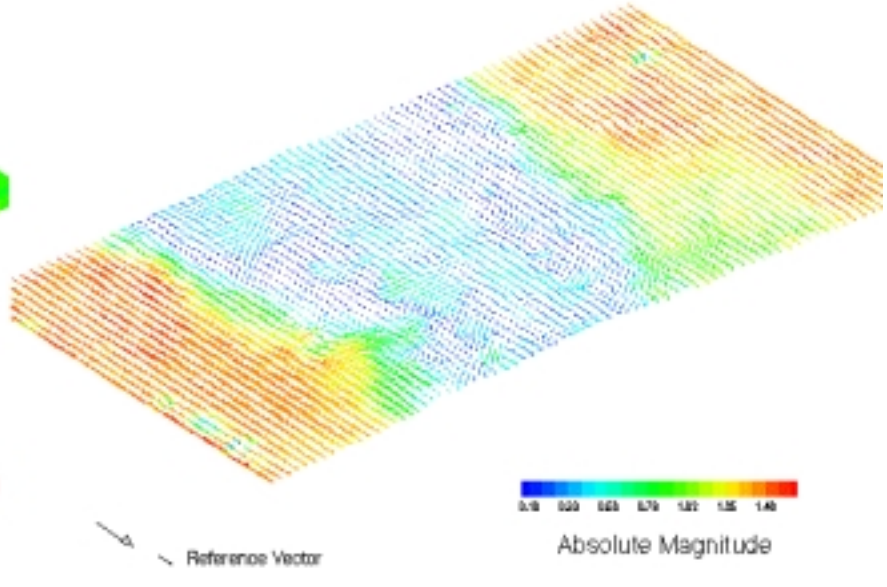
Boattail Case
Horizontal Plane at Half Height



Vorticity

Flow Direction

Boattail Case
Horizontal Plane at Half Height

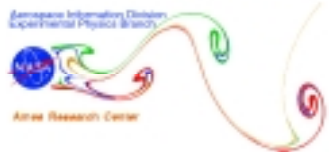


Absolute Magnitude

Reference Vector

Future Plans

- **Document experimental results**
  - **NASA TM**
  - **SAE meeting paper**
  - **Post to internet**
- **Test more realistic geometries**
  - **Gap studies**
  - **Tractor details**



Summary

- **1/8-scale truck model tested in Ames 7x10**
- **Results show significant drag reduction with the addition of boattail plates**
- **Significant Reynolds number effect observed below Re = 1 million**
- **Large data set available for CFD validation**